NAVAL AIR DEVELOPMENT CENTER

WARMINSTER, PA 18974

REPORT NO. NADC-72061-SD 18 APRIL 1972

EVALUATION OF TACTICAL OUTLAY

PHASE REPORT

AIRTASK A503-503A/202E/0F018-02-03-0
Work Unit 6

Approved for public release; distribution unlimited

DEPARTMENT OF THE NAVY
NAVAL AIR DEVELOPMENT CENTER
WARMINSTER, PA. 18974

Systems Analysis and Engineering Department

REPORT NO. NADC-72061-SD

18 April 1972

Evaluation of Tactical Outlay

PHASE REPORT

AIRTASK A503-503A/202E/0F018-02-03-0
Work Unit 6

Prepared by: D. F. Gould

Reviewed by: C. A. DeCrescente

Approved by: W. H. Raber
Director

Approved for public release; distribution unlimited

INTRODUCTION

This report defines a quantity called tactical outlay, or cost, and describes a procedure for its evaluation. Tactical cost, a quantity of importance in tactical decision making, is, briefly, the value of what is given up when a specific course of action is taken. The procedure to be described was developed as one phase of studies of the military worth of information, as reported in reference (a). The procedure and the associated rationale are also expected to be of use in future analyses of command and control systems, reconnaissance systems and other systems which provide information to decision makers.

Tactical cost finds its application in decision making. Therefore, the first section in the discussion describes the decision maker model which represents the framework within which the concept of tactical cost is developed. The second section defines tactical cost. The third section lays out the basic steps in its evaluation. A fourth section deals with examples to illustrate the procedure and to bring out points not previously developed.

THIS PAGE BLANK

DISCUSSION

THE DECISION MAKER MODEL

Tactical cost is a quantity of importance to decision makers in general. It is of most direct importance to those decision makers whose decision criterion is the maximization of net return from the expenditure of a quantity of some scarce resource. It is believed that certain military decision makers, if not all, fall into this category. In any case, the decision maker model prepared for studies, reported in reference (a), of the military worth of information includes a decision maker using this type of criterion. The decision maker in this model is a military officer controlling one phase of an on-going military action. The model is described in some detail in the following because its elements and characteristics determine or bear on the elements and characteristics of tactical cost.

In the general decision maker model the decision maker is seeking some goal and identifies certain courses of action which will take him to it. The decision problem is to choose one of the courses of action. As normally laid out, the procedure is to predict quantitatively the results which would be realized for each of the courses of action, to assign a value to each of the results, and then to choose the course of action for which the predicted result has the highest value. It should be noted here that the word "value" is used with the sense of worth or significance rather than number or magnitude.

In the decision maker model as specialized, the decision maker is charged with performing a mission with a set of forces assigned for the purpose. The mission is part of a larger, on-going military action. The decision maker is regarded as having a limited time in which to perform the mission. He is limited by doctrine and by the tactical situation as to type of decisions.

The decision maker must accomplish the assigned mission with a set of functional units such as aircraft, tanks, platoons. Such units are included in the forces available. The functional units, however, are part of an organization which supports the units with respect to maintenance, logistics, and control of operations. The functional units, together with the supporting organization, can be considered to represent a system which over a reference period of time has the capability of turning out a certain quantity analogous to physical work. The decision maker can be viewed as having this quantity as capital with which to operate in the present and future missions. The reference period is one of significance in the operation of the system. It may be the time interval to the next occasion when replacements become available. The important fact is that the resources available to the decision maker for the accomplishment of both the present and certain future missions are limited.

The decision maker may have as courses of action the various ways he can allocate components of forces to the several tasks or the various procedures which might be used. He evaluates each course of action with respect to net achievement. That is, for each course of action he evaluates the anticipated positive achievement and the anticipated tactical cost and subtracts the one from the other. Positive achievement is calculated using an equation relating the output of the functional units mentioned above to the mission purpose. The preparation of such equations is discussed in reference (a) and will not be treated further here. Having evaluated the net achievement that he can expect to be realized for each course of action, the decision maker then selects that course of action which promises the maximum net return.

In general, a decision maker must make decisions in the present concerning activities which will be carried out in the future. Thus, when the evaluation of a course of action is made, it represents a prediction of the circumstances to be encountered. Because prediction is involved, there must also be uncertainty. The uncertainty is dealt with in the decision maker model by the methods of probability as indicated in reference (a). One result of the fact that uncertainties are dealt with is that quantities to be discussed in the following section have the significance of expected values.

The basic elements in the decision problem - the military situation, the assigned mission, the system with which the decision maker must accomplish the mission, the courses of action open to the decision maker - are also important factors in the determination of tactical cost, as will be seen in the following sections. The material which follows embodies the assumption that these elements have been defined prior to the beginning of the effort to evaluate tactical cost.

DEFINITION OF TACTICAL COST

In the decision model discussed above, the worth of the results realized by following one of a set of courses of action is set equal to the (expected value of) net achievement. The establishment of a system for assigning worth or utility to results is a key part of a decision theory analysis. In this case, a decision maker model specialized for a tactical military situation, it has seemed reasonable to postulate that the decision maker acts to maximize the degree to which he accomplishes the purpose of the assigned mission while having regard for certain constraints. One constraint postulated is that the anticipated tactical achievement, achievement of the purpose of the mission, using an approach embodied in a set of courses of action must at least equal the achievement which could be expected in another approach. Another constraint is the fact that resources must be husbanded for future missions. The maximization and constraints, it is believed, are best accounted for by maximizing the net achievement when the tactical cost or negative component of achievement includes the two constraint factors. Then, tactical cost is defined as the sum of what could be achieved with the

system at the disposal of the decision maker in the average alternative mission, and the average value of the achievement which could have been realized in the future by that part of the system which is used up, worn out, or attrited.

Tactical cost defined in this way is a generalization of the normal economic cost. If I buy an article with money from limited funds, there are two aspects of the article which are of economic interest - the value of the article, and the cost of the article. These aspects are independent except as I consider them in the decision to buy. Value is analogous to positive achievement and need not be considered further. The cost of the article is by custom the number of dollars represented in the purchase price. However, in a more penetrating sense, the cost is the value of what I must give up to get the article. If I spend N dollars for the article, then I do not have them to spend, now or in the future, for other goods or services. Thus, the economic cost of the article is really the average value I could realize spending the same amount of money on other things. My decision to buy, presumably, results from the fact that the value of the article, to me, is greater than the cost, that is, greater than the value of the generalized alternative.

Tactical cost defined in this way is seen to be dependent on the situation in which it is assessed. However, since decisions made in real life are known to depend on the situation, it is unlikely that costs could be assessed without reference to the situation while retaining verisimilitude.

BASIC STEPS IN THE EVALUATION OF TACTICAL COST

The process of evaluating tactical cost for a particular decision situation can be carried out in four steps which are listed as follows and defined below.

1. Selection of an elemental quantity (measure of effectiveness)
2. Evaluation of the functional unit system capability for unit time
3. Evaluation of the reference time interval
4. Evaluation of present system capability used and future capability lost for each course of action

A first step toward the evaluation of the tactical cost in a particular situation is the selection of an elemental quantity or measure of effectiveness, a quantity which corresponds to the dollar. One requirement on this quantity is that both tactical achievement and tactical cost be expressible in terms of it, as value and cost or profit and loss are expressible in terms of the dollar. Thus, the elemental quantity must be chosen with regard for the purpose of the mission. The elemental quantity can often be chosen as one doctrinally associated with the functional unit. For example, the "sortie" is an elemental quantity often associated with

aircraft. There must be coupled with such an elemental quantity, however, the notion of value or effectiveness. That is, for aircraft, the elemental quantity must be actually "a sortie of average effectiveness." In many applications it will not be necessary to evaluate "average effectiveness," just as in the case of the dollar cost the average value of the alternative purchase is not ordinarily determined. To some extent the choice of the elemental quantity may be arbitrary. The dollar could possibly be adapted to any case. However, there are implications of the dollar as elemental quantity which may be avoided advantageously in some cases. Further, evaluations will often be found to be easier to perform and to interpret later if the elemental quantity is closely related to the military role of the functional unit.

The second step is the evaluation of the capability of the system of functional units and their support over unit time. As an example, take the system to be a fleet of trucks and assume that the elemental quantity has been chosen as the ton-mile. Then, the problem might be to determine how many ton-miles of cargo transport can be accomplished by the fleet in a day. Such a determination might take into account the reliability of the trucks, the speed and capacity of the trucks, the effectiveness of the maintenance force, and possibly other factors such as the state of the roads and the availability of fuel and cargo. The capability of the system is to be determined in terms of the elemental quantity. This step is a major one in complexity; however, it can be expected that mathematical models will be available, constructed for other purposes, which can be used in the evaluation. For example, sortie rate models are available for carrier-based aircraft. Or, and preferably, operational data may be used.

In the second step it will often be found that the set of functional units is not homogeneous. The functional units may differ in kind or capability. In most cases the lack of homogeneity can be dealt with through the use of weighting factors. One type of functional unit is taken as a reference and the others are evaluated in terms of it.

The third step is the evaluation of the reference time interval. There may be significant time intervals which relate to the carrying out of the mission. However, the reference time interval is not associated with a particular mission; it is a time period over which missions will be carried out in the future, after the present mission is complete. This interval is that over which the reservoir of capability now available must be used as effectively as possible. Thus, the reference time interval bears on the importance of future achievement lost due to attrition relative to the present achievement given up by expending capability in the present mission. The evaluation of this interval can ordinarily be achieved by considering the military situation. The interval might be identified with the period of a replenishment cycle. Or the interval might be the time that the military unit stays on station or on line.

The final step in the evaluation of tactical cost is to determine for each course of action the system capability expended, including future

capability risked in say the loss of functional units to enemy action or accident. The system capability expended can often be assessed as the capability per functional unit per unit time multiplied by the number of units and the time required to carry out the course of action under consideration. To this would be added the expected number of functional units lost multiplied by their capability per unit time multiplied by the time remaining in the reference interval.

It should be noted that while the procedure has been indicated to be divisible into neat, independent steps, such division is not actually practical. The real procedure uses the steps but in a cyclical manner so that perhaps the first step is done tentatively and the other steps are tried with results that cause a return to the first step and choice of another elemental quantity.

APPLICATION

In order to illustrate the procedure offered for the evaluation of tactical cost, two cases are examined. The cases differ in the level of command at which the decision maker operates as well as in the other details. In the following, there is no attempt to assess tactical cost quantitatively; rather, the attempt is to show the logical nature of the approach.

Case I

In this case, the situation is that an attack aircraft armed with standoff missiles is in the course of attacking a distant target. One missile has been fired and has completed its flight. The decision maker in this case is the member of the aircraft crew who has the responsibility of operating the missiles. The courses of action open to this decision maker are to fire another missile or to stop at this point and return to base with the remaining missiles. It is assumed that the missiles need not be jettisoned but can be put in a safe condition for the landing. The mission of the aircraft in this case is taken to be: "Destroy or damage bridge X for the purpose of decreasing the enemy's resupply capability in the area served by the bridge." In this case it can be seen that the functional units are the missiles and the aircraft from which they are launched.

The first step is the selection of the elemental quantity. It appears advantageous to select the unit "ton-mile" for this purpose. The functional units involved can reasonably be characterized in terms of the distance over which they can carry a particular load of explosives. This elemental quantity also fits in with the purpose of the mission, which can be interpreted as depriving the enemy of ton-miles of supply capability. Note that the "ton" of the elemental quantity must have the significance of a militarily useful ton. Other elemental quantities might be missile sorties or vehicle flight hours of average military accomplishment.

The second step is to examine the functional units and establish a basic capability for the time of the mission under consideration. The missiles can be rated as to capability by their warhead weight multiplied by the range over which a missile can deliver the warhead with, say, reasonable effect. A missile ordinarily has a nominal effective standoff range assessed for analysis purposes. This value is suitable for use in this application. The aircraft can be rated in terms of its nominal radius and load carrying capacity with a weighting factor representing the effectiveness of a bomb from the aircraft, considering its weapon delivery system, relative to the warhead of the missile.

The third step involves the determination of the reference time interval. In this case the time interval is found to interact with the nature of the cost factors included in step four. As a result of this interaction, the time interval is not simply the time interval of missile launch or flight. It may be the time before replacement aircraft can be supplied to the carrier from which the missile launching aircraft has come.

The fourth step is the evaluation of the tactical cost for each of the courses of action. The first possible course of action is to fire another missile. The tactical cost here is the capability represented by the missile plus a possible cost component represented by risk to the aircraft and remaining missiles which may accompany the use of the missile. In the case where the aircraft must remain over enemy territory and within a relatively restricted area during the flight of the missile (where the missile is not of the fire-and-forget type), there may be important possibility of attack on the aircraft by enemy fighters. Then, this component of cost would be the probability of loss of the aircraft times its capability integrated over the reference time interval. Tactical cost for this course of action is the sum.

The alternative course of action is to stop and return to base. The cost of this course of action must be set at zero because no more missiles are used up and there is no risk of the aircraft comparable to that for the other course of action.

The cost procedure can be expected to vary with the nature of the courses of action even for the simple situation set up for case I. In a closely related case the courses of action might be to fire the next missile from the same range or to close to a shorter range before firing. Or the decision might be between firing one missile or a salvo of two. Either variation calls for a change in the cost procedure.

Case II

The situation is that in which a group of attack aircraft has been armed and briefed fully and is enroute to a pair of targets. There is a basic planned division of the aircraft between the two targets; there is also an alternative division which the group will use if the

decision maker transmits a prearranged signal. In this case the courses of action are to let the strike go forward according to the basic plan, or to switch to the alternate plan. In this case the functional units are the aircraft. The mission can be taken to be to attack aircraft on the ground at each of two airfields for the purpose of depriving the enemy of their use for as long as possible.

The elemental quantity flight-hour can be chosen in this case because the functional unit capability can reasonably be stated in terms of flight-hours; achievement of the purpose of the mission can also be evaluated in terms of this quantity. Alternatively, the ton-mile could be used. These quantities are convertible one into the other.

The costs of the two courses of action are the total number of flight hours expended in the attacks on the two targets plus future flight hours risked. The costs will differ, in general, for the two courses of action when the distances to the targets differ and when the defenses enroute and at the target differ.

In the cases discussed above, and in general, the procedure does not offer a formula for establishing the cost represented in the loss of a human life, such as that of an air crew member. Rather, the assumption is made that part of the organization that supports the operation of the functional units is a search and rescue element which recovers the crews of most attrited functional units. Crews are either recovered by this element or are captured and held prisoner by the enemy.

REFERENCE

(a) Naval Air Development Center Report No. NADC-SD-7066 "Evaluation of the Military Worth of Information" (Vol I Unclassified, of 15 Oct 1970) (Vol II SECRET, of 15 Oct 1970)

DOCUMENT CONTROL DATA - R & D

Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified

1. ORIGINATING ACTIVITY (Corporate author)
Systems Analysis and Engineering Department
Naval Air Development Center
Warminster, Pennsylvania 18974

2a. REPORT SECURITY CLASSIFICATION
UNCLASSIFIED

2b. GROUP

3. REPORT TITLE

EVALUATION OF TACTICAL COST

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Phase Report

5. AUTHOR(S) (First name, middle initial, last name)
David F. Gould

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
18 April 1972	9	1

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO. Airtask A503-503A/202E/0F018-02-03-0	NADC-72061-SD
c. Work Unit 6	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Naval Air Systems Command (AIR-5031) Department of the Navy Washington, D. C. 20360

13. ABSTRACT

A procedure is given for the evaluation of tactical cost. Tactical cost, often a component of utility in decision making, is, briefly, the value of what is given up as a result of adopting a specific course of action.